Quality Improvement Of Inverter Voltage With Increasing Switching Frequency

Mohamad Rodhi Faiz
Department of Electrical Engineering
State University of Malang (UM)
Malang, Indonesia
mohrodhifz@gmail.com

***Abstract*— This study aims to look the behavior of the voltage due to changes in the inverter switching frequency. Inverter in this study using a MOSFET that controlled with NI sb-9606, NI RIO 9683, and integrated with the computer. The study was conducted by looking at the behavior of the inverter output voltage with various switching frequency setting. Setting between 2000 and 20000 Hz show the value of the RMS voltage will increase for the higher switching frequency. But the increase in switching frequency will cause MOSFET and transformer to rapid heat.**

***Keywords*— Inverter; NI 9683; NI sb-RIO 9606; Switching Frequency**

I. INTRODUCTION

DC to AC conversion is most commonly used of MOSFET inverter circuits, which can switch the voltage across the load, providing a digital approximation of the desired AC signal. The simplest variant of this inversion is the production of a square wave approximation of a sine wave. For a square wave, the load voltage must be switched merely from high to low, without the need for an intermediate step. In order to deliver the same power as the sine wave to be approximated, the amplitude of the square wave must be the sine wave's RMS value. This way, the average voltages, and therefore the power delivered, will be the same for the two waveforms. Square wave inverters are very rarely used in practice, as many devices which utilize timing circuits that rely on something close to the sine wave from the power company cannot operate with such a rough approximation. In addition, a square wave has relatively large 3rd and 5th harmonic components, which burn power and severely cut down on the efficiency of devices using such inverters as a power source.

A very common upgrade to the square wave inverter is the modified sine wave inverter. In the modified sine wave inverter, there are three voltage levels in the output waveform, high, low, and zero, with a dead zone between the high and low pulses. The modified sine wave is a closer approximation of a true sine wave than is a square wave, and can be used by most household electrical devices. As such, it is extremely common to see this type of inversion in commercial quality inverters. Despite being much more viable than a simple square wave the modified sine wave has some serious drawbacks. Like the square wave, modified sine waves have a large amount of power efficiency loss due to significant harmonic frequencies, and devices that rely on the input power waveform for a clock timer will often not work properly. Despite the inherent drawbacks, many devices can work while powered by a modified sine source. This makes it an affordable design option for such implementations as household uninterruptible power supplies [1,2].

The best power source for most applications is a pure sine wave. All low power household plug-in devices are designed to work with this source and, as such, will be most likely to work properly and most efficiently on such a source [4,5]. A true sine wave source is produced most easily for high power applications through rotating electrical machinery such as naval gas-turbine generators, house-hold diesel or gasoline backup generators, or the various generators employed by power companies that employ a shaft torque to create an AC current. These sources provide a relatively clean, pure sine wave (lacking significant harmonics and high frequency noise) thanks to their analog rotational make-up. Such rotating machinery can be inappropriate for low-power backup supply usage due to their high cost, large size and required maintenance. As such, a smaller, digital pure sine wave inverter can be extremely useful.

The most common and popular technique of digital pure-sine wave generation is pulse-width-modulation (PWM) [1,2]. The PWM technique involves generation of a digital waveform, for which the duty-cycle is modulated such that the average voltage of the waveform corresponds to a pure sine wave. The simplest way of producing the PWM signal is through comparison of a low-power reference sine wave with a triangle wave. Using these two signals as input to a comparator, the output will be a 2-level PWM signal. This PWM signal can then be used to control switches connected to a high-voltage bus, which will replicate this signal at the appropriate voltage. Put through an LC filter, this PWM signal will clean up into a close approximation of a sine wave. Though this technique produces a much cleaner source of AC power than either the square or modified sine waves, the frequency analysis shows that the primary harmonic is still truncated, and there is a relatively high amount of higher level harmonics in the signal. This study provides the behavior of the inverter output voltage with various switching frequency setting.

II. EXPERIMENT

A. Inverter Hardware

Figure 1 shows the work principle of the inverter that used for experiment. Computer connected with GPIC (General Purpose Inverter Controller) use LAN cable. Port HBDO of GPIC connected with MOSFET. The NI Single-Board RIO General-Purpose Inverter Controller (GPIC) is designed for high-volume and OEM embedded power electronics control, DAQ, and analysis applications that require high performance and reliability. Featuring an open, embedded architecture, small size, and flexibility, hardware device can help to get custom embedded power electronics control system quickly. The NI Single-Board RIO GPIC can take advantage of FPGA performance and reliability with relatively low nonrecurring engineering compared to custom hardware design. Using the flexibility and rapid prototyping capabilities of the NI LabVIEW graphical system design toolchain can significantly reduce the development time of power electronics control application and customize it based on design requirement.

Fig. 2. shows resistor circuit used as a voltage divider where R_1= 1 Mega Ohm and R_2 = 22 Kilo Ohm. The output voltage can be obtained by equation below:

$$V\ out = \frac{R2}{R1 + R2} \times Vin$$

$$= \frac{22.000}{1.000.000 + 22.000} \times 220 = 4{,}7\ \mathrm{V} \quad (1)$$

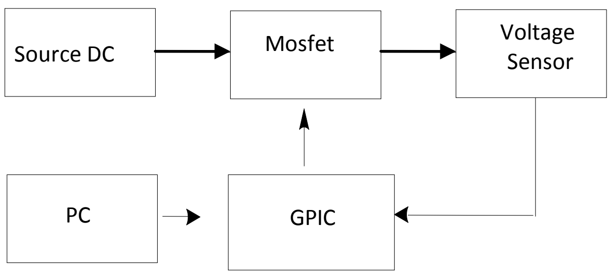

Fig. 1. Block Diagram

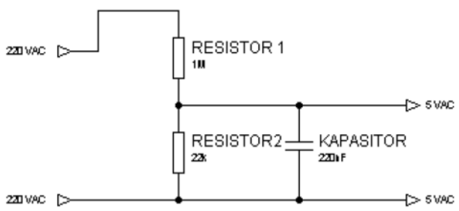

Fig. 2. Voltage sensor

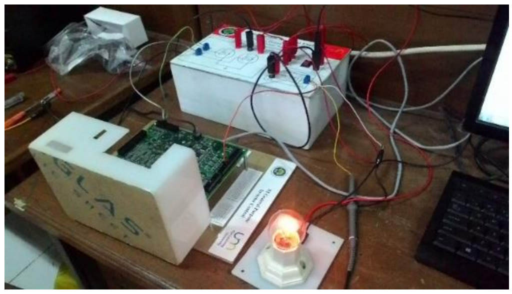

Fig. 3. GPIC and MOSFET

B. Inverter Software

In order to create a signal which is closer to a true sine wave, a 3 level PWM signal can be generated with high, low, and zero voltage levels. For the resulting 3-level PWM signal to correspond to a sine wave, the signal comparison stage must also be 3-level (figure 4). A triangle wave is used as it is in the 2-level PWM comparison, but it half the amplitude and summed with a square wave to compare one half of the sine reference signal at a time. The resulting PWM signal is used to control one half of an H-bridge , which controls how long the bus voltage is allowed through to the load. The other half of the H-bridge controls the polarity of the voltage across the load, and is controlled by a simple square wave of the same frequency and in phase with the sine signal. Generally, this square wave can simply be created in a stage of the sine wave generation circuit. The resulting 3-level high-voltage PWM signal can be filtered into a very close approximation of the desired sine wave. It should be noted that the simulations we did for this technique utilized a very low switching frequency for the triangle wave, so the PWM switching frequency is also low. This was done so that the waveforms would be easy to view and understand. In reality, a switching frequency above 20 kHz would be used to keep inductance ringing outside the range of human hearing [3].

GPIC can control time switching of MOSFET. A program is developed from the fundamental concept of the SPWM switching technique by using Labview [4]. The program is capable to produce the SPWM waveform characteristic over several ranges of frequencies, modulation and number of pulses. The input data is processed through a mathematical programming and the intersection between reference signal and carrier signal generates PWM pulses for a period in each pulse. In Labview a program is as block diagram. In this experiment use three bock diagram: sinus signal generator, SPWM signal generator, and voltage sensor. Figure 5, 6, 7 show the block diagram of program.

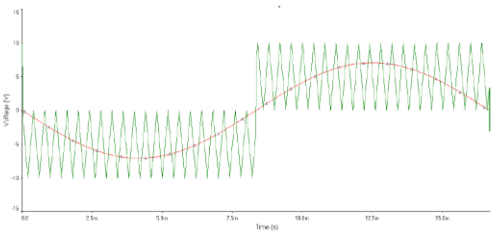

Fig. 4. 3-Level SPWM

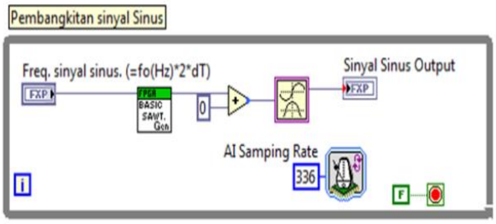

Fig. 5. Sinus Signal Generator

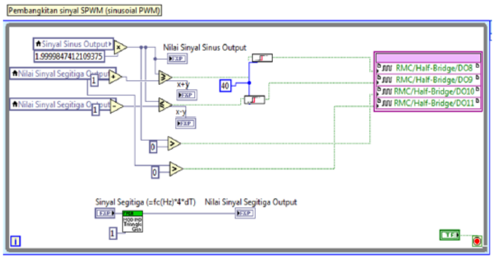

Fig. 6. SPWM Signal Generator

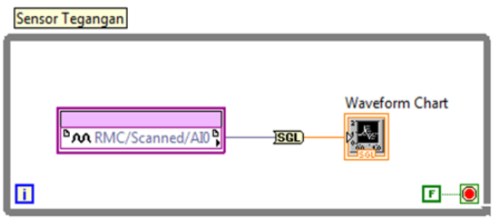

Fig. 7. Voltage Sensor

III. Results

Oscilloscope is used to measure the output voltage from inverter. The experiment was conducted for switching frequencies between 500 Hz until 20000 Hz. Table 1 demonstrate the value difference of RMS voltage for switching frequency 500 Hz until 20000 Hz respectively. The RMS voltage will increase if the frequency switching increased.

Respectively, figure 8 – 11 show the inverter output signal with difference switching frequency. If switching frequency increased, the inverter output signal will be smoother. It means the RMS voltage of the output inverter increased

TABLE I. THE VALUE OF RMS VOLTAGE FOR SWITCHING FREQUENCY 500 HZ UNTIL 20000 HZ

No	Frekuensi Swithing (Hz)	Vrms (Volt)
1	*500*	*201*
2	*1000*	*211*
3	*2000*	*228*
4	*4000*	*256*
5	*6000*	*274*
6	*8000*	*299*
7	*10000*	*318*
8	*12000*	*333*
9	*14000*	*349*
10	*16000*	*361*
11	*18000*	*379*
12	*20000*	*399*

Fig. 8. Inverter Output with Frequency switching 500 Hz

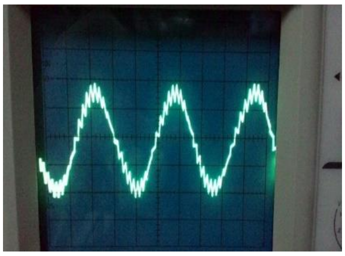

Fig. 9. Inverter Output with Frequency switching 1000 Hz

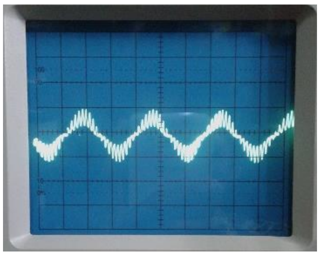

Fig. 10. Inverter Output with Frequency switching 4000 Hz

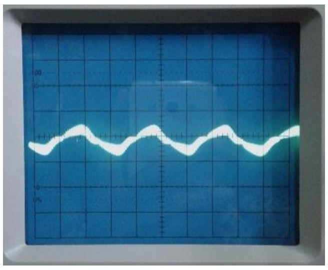

Fig. 11. nverter Output with Frequency switching 10000 Hz

IV. CONCLUSIONS

This experiment has showed a method to obtain the switching pulses in generating a SPWM signal for a single-phase inverter. The SPWM signal has been designed and tested using LabVIEW and implemented on GPIC that control a pair of MOSFET. The switching frequency, number of pulses over a period and the output frequency can be easily changed using the program. The SPWM signal is uploaded on GPIC Board and it capable to provide flexibility, reliability and easy to program in order to control a single-phase inverter.

The experiment shows the RMS voltage of inverter output will be increased for the higher switching frequency. But the increase in switching frequency will cause MOSFET and transformer to heat faster.

ACKNOWLEDGEMENTS

I thank head of Electrical Departmant Laboratory, Siti Sendari who lend equipment of experiment, I thank my student, Vania Aprillia Ukhti who lend student version labview software with p/n 501722U-00 and I thank too the best my student Davin Fitra Andriza who help me to do experiment. I can only pray may God bless all of you.

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